

SINGLE PHASE SAMPLING APPARATUS AND METHOD

[001] This application claims the benefit of U.S. Provisional Application 60/406,619, filed August 27, 2002.

FIELD OF THE INVENTION

[002] This invention relates generally to formation fluid testing and collection apparatus and more particularly to a single phase collection apparatus for a formation evaluation tool that collects formation fluids at a predetermined pressure and maintains the collected fluid pressure at such pressure throughout the sampling operation.

BACKGROUND OF THE INVENTION

[003] In the oil and gas industry, a drilling fluid ("mud") is used during drilling of a wellbore to facilitate the drilling process and to maintain a hydrostatic pressure in the wellbore greater than the pressure in the formations surrounding the wellbore. This drilling fluid penetrates into or invades the formations for varying radial depths (referred to generally as the invaded zones) depending upon the types of the formation and drilling fluid used. Wireline formation testing tools lowered into the mud of the wellbore are used to monitor formation pressures, collect formation fluid samples from the wellbore and to predict performance of reservoirs around the wellbore. These formation evaluation tools typically contain an elongated body having an elastomeric packer that is sealingly urged against the zone of interest in the wellbore. Fluid is collected and brought to the surface for analysis to determine the properties of the fluids and the conditions of the zones or formations from where the fluids have been collected. During this process, it is critical that only uncontaminated fluids are collected, and in the same condition in which they exist in the formation.

[004] Formation evaluation tools typically collect formation fluid by transferring such fluids from a probe into a sample chamber. Prior art formation evaluation tools such as sequential formation testers and repeat formation testers used large collection chambers that varied in size from one to five gallons to collect samples. Samples were not pumped into the chamber, but were forced into the chamber by the hydrostatic pressure of the formation acting against the atmospheric pressure in the chamber. The problem with these chambers was that once opened at the formation zone, they would ingest not only the sample, but also surrounding mud, rocks and other contaminants. Current formation testing tools overcome this problem by first testing fluids from the desired formations or zones of

interest to ensure that the fluid is substantially free of mud filtrates, and then collecting fluids by pumping formation fluid into one or more sample bottles associated with the tool.

[005] Because of the great difference in pressure between the formation (hydrostatic) and the interior of the sample bottle (atmospheric), there is a possibility that the formation fluid pumped into the chamber will vaporize, or “flash,” due to a great decrease in pressure. In order to prevent or reduce the chances of the liquid vaporizing from a decrease in pressure, formation fluid is pumped into the chamber at a relatively slow rate. In addition, the tools are often equipped with restrictions to slow down the fluid flow rate into the chamber. Water cushions are also utilized to fill the chambers more uniformly. However, it is common for the collected single phase fluid to separate into a two phase sample containing vaporized gas. If the sample fluid pressure is reduced prior to arrival in the analysis lab, a lengthy procedure is required to recombine the sample back into a single phase as it was in situ. Additionally, asphaltenes are commonly present in the hydrocarbons and if the pressure in the chamber remains at a relatively low pressure, such asphaltenes tend to flocculate to form gel-type masses in the fluid. The flocculation process is substantially irreversible. Thus, it is desirable to withdraw and maintain the sample fluid at a pressure above the bubble point to maintain it in a single phase.

[006] Additionally, the temperature difference between the surface elevation and the formation elevation can exceed several hundred degrees Fahrenheit. As the tool is retrieved, the chamber temperature drops, causing the pressure in the chamber to drop. This substantial pressure drop in the chamber can result in the pressure of the formation sample dropping below the bubble point, resulting in a multi-phase sample.

[007] Attempts have been made to maintain the fluid sample in a single phase by applying a pressurized nitrogen charge against a sample piston located in the chamber. This forces the sample piston against the fluid sample to maintain its pressure at a sufficient level to prevent a phase change upon retrieval. However, this system is complex and requires the use of nitrogen at a pressure of over 20,000 psi. The danger and inconvenience of working with nitrogen at this extremely high pressure discourages its use.

[008] The present invention addresses the above noted problems and provides a single phase collection apparatus in which collected formation fluid is maintained at a predetermined pressure above the bubble point to maintain the sample in a single phase. No water cushions are required to uniformly fill the chambers. The tool also automatically

maintains the chamber pressure above the bubble point pressure during the entire sampling operation regardless of the change in the temperature surrounding the chamber.

SUMMARY OF THE INVENTION

[009] The single phase collection apparatus of the present invention is therefore designed to maintain wellbore formation samples at a pressure above the bubble point as the sample is removed from the wellbore and is transported to a laboratory for analysis. By utilizing a nitrogen gas charge that acts against a sample piston, the sample is maintained at a pressure above the bubble point of the sample, thereby preventing the sample from separating into two phases. However, the nitrogen pressure utilized in this collection apparatus is significantly lower than the pressure used in existing single phase collection designs, and is therefore safer and easier to use. The amount of pressure present in a commercial nitrogen bottle generally will be sufficient to pre-charge the apparatus, without the need for nitrogen gas boosters to achieve the high pressures required.

[0010] The present invention modifies an existing Department of Transportation (“DOT”) exempt sample bottle, simplifying DOT approval. Utilization of sample bottles that can be shipped as freight improves sample quality because the sample does not need to be transferred for transport. The use of these currently available sample bottles also allows in-the-field modification of existing DOT sample bottles. No additional leak paths for the sample are introduced by the modification, unlike older Drill Stem Test single phase samplers that created multiple leak paths with sliding seals and port crossing seals that affected the reliability of the devices. In addition, unlike the older designs which were limited to sample sizes of around 400 to 500 cubic centimeters due to the complexity of the mechanism, the simplified new design allows for the acquisition of larger sample sizes that may be more than twice that of existing designs. This is because the new design does not have any valves to shift, fluid to port or any other items to complicate and use up formation sample space. In addition, the size of the sample can be changed as desired because the nitrogen pressure can be adjusted for each sampling operation. A higher initial pressure is used to retrieve a smaller sample.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig. 1 illustrates a standard sample bottle.

[0012] Fig. 2 illustrates the lower portion of a standard sample bottle modified according to the present disclosure.

- [0013] Fig. 3 illustrates the sample piston and nitrogen charging piston being forced to the bottom of the bottle.
- [0014] Fig. 4 illustrates pressurized nitrogen gas being forced into the nitrogen gas chamber.
- [0015] Fig. 5 illustrates a sample bottle prepared for use.
- [0016] Fig. 6 illustrates hydrostatic pressure forcing the nitrogen charging piston upwards.
- [0017] Fig. 7 illustrates formation fluid being pumped into the sample chamber.

DETAILED DESCRIPTION OF THE INVENTION

[0018] The Single Phase Sample Collection Apparatus utilizes an existing sample bottle modified to allow for the introduction of pressurized nitrogen gas that acts against a sample piston of the device to maintain the sample at or above the bubble point of the sample. The collection apparatus utilizes the hydrostatic pressure present at the depth of the desired formation sample to compress the nitrogen gas “pre-charge” to the pressure of the formation sample, then maintains that pressure as the collection apparatus is removed from the wellbore.

[0019] Fig. 1 illustrates an existing formation evaluation tool sample bottle **10** designed to contain a formation sample located in a collection chamber **2**. When at the desired formation depth, the formation sample is pumped into the collection chamber **2**, pushing the sample piston **1** downwards until it comes into contact with an end cap located at the bottom of the sample bottle **10**.

[0020] The present invention single phase collection apparatus **20**, as shown in Fig. 2, utilizes a current version sample bottle **10**, but it is equipped with a nitrogen charging piston **3** inserted into the bore of the sample bottle **10**. The sample bottle **10** is preferably a standard sample bottle that can be shipped as freight. The use of a sample bottle that can be shipped as freight improves sample quality because the sample does not need to be transferred to a separate shipping bottle for transport. The nitrogen charging piston **3** is positioned between the sample piston **1** and an end cap **4**. The addition of the nitrogen charging piston **3** into the sample bottle **10** creates a variable size nitrogen gas chamber **6** between the nitrogen charging piston **3** and the sample piston **1**.

[0021] The sample piston **1** is preferably made of an alloy steel, but can also be constructed from stainless steel, corrosion resistant alloy metals or other material with the appropriate properties to withstand the temperatures, pressures and corrosive conditions associated with such a device.

[0022] The nitrogen charging piston **3** is preferably made of an alloy steel, but can also be constructed from stainless steel, corrosion resistant alloy metals or other material with the appropriate properties to withstand the temperatures, pressures and corrosive conditions associated with such a device. The nitrogen charging piston **3** is sized to fit precisely within the bore of sample bottle **10**. Gases are prevented from escaping around the nitrogen charging piston **3** by the use of one or more O-ring seals fitted into grooves inscribed into the outside diameter of the piston. An anti-extrusion backup seal may be placed on the low pressure side of the seal to help improve the seal. The nitrogen charging piston **3** has an open axial bore **9** allowing for the communication of gas through the piston. A check valve **5** is located within the axial bore **9** of the nitrogen charging piston and controls gas communication through the piston, into and out of the nitrogen gas chamber **6**. Check valve **5** could also be a different type of valve such as a manually operated open/closed valve. A plunger **7**, with a narrowed diameter section, fits into nitrogen charging piston **3**. The plunger **7** is preferably threaded to allow engagement with matching threads on the inside diameter of the axial bore **9**. When the plunger **7** is fully inserted into the piston **3**, the narrowed diameter section of the plunger **7** functions to open check valve **5**. The plunger **7** has an axial bore running through it with a removable release plug **8** to close off the end of the axial bore. O-ring seals at the outside diameter of the plunger **7** prevent gases from escaping around the plunger.

[0023] A case adaptor **11** with anti-rotation lugs **12**, fits into and locks into the end of the sample bottle **10**, and engages nitrogen charging piston **3** when the piston is pushed up to the end of its stroke. When engaged, the anti-rotation lugs **12** prevent the nitrogen charging piston **3** from rotating with respect to the lower case adaptor **11** so that the plunger **7** may be rotated for insertion/removal. The end cap **4** is inserted into and engages the case adaptor **11**. The end cap **4** comprises a port **15** that is open to hydrostatic pressure when the collector apparatus is inserted into a wellbore, thereby exposing the nitrogen charging piston **3** to hydrostatic pressure.

[0024] In order to collect a formation sample, the single phase collection apparatus **20** is assembled as shown in Fig. 2. As shown in Fig. 3, the end cap **4** is removed and an air

pressure source is connected to the sub 13. Air pressure at approximately 100 psi is then introduced into the collection apparatus, forcing the sample piston 1 and the nitrogen charging piston 3 down towards the case adaptor 11. The nitrogen charging piston 3 stops when it reaches the case adaptor 11, and the anti-rotation lugs 12 engage the nitrogen charging piston 3 thereby preventing rotation with respect to the case adaptor 11. Release plug 8 is then removed to allow any trapped gases between the sample piston 1 and the nitrogen charging piston 3 to escape, thereby minimizing the volume between sample piston 1 and the nitrogen charging piston 3.

[0025] The plunger 7 is then removed from the nitrogen charging piston 3 and a purge adapter 14, connected to a pressurized nitrogen supply, is inserted into the nitrogen charging piston 3, opening the check valve 5, as shown in Fig. 4. The air pressure source attached to the sub 13 is removed and nitrogen gas is forced through the purge adaptor 14, through the check valve 5, and into the nitrogen gas chamber 6. As nitrogen gas fills the nitrogen gas chamber 6, the sample piston 1 is forced upwards until nitrogen gas fills nearly the entire volume of the sampler. Although nitrogen gas is the preferred pressurizing medium, it is conceivable that other pressurizing gases could be utilized to achieve the same function. However, nitrogen has the advantages of easy availability and has well known physical properties. Once this pre-charging pressure reaches the proper level, preferably around 3,000 psi, the purge adapter 14 is removed, thereby closing off check valve 5. The release plug 8 is then reinstalled in the plunger 7, and then the plunger 7 is reinstalled into the nitrogen charging piston 3. The narrowed diameter section of the plunger 7 opens check valve 5, allowing nitrogen gas to act against the O-rings of the plunger 7. This prevents the formation of any regions in the apparatus with only atmospheric pressure, which would increase the differential pressure acting on the seal. The end cap 4 is then replaced, as shown in Fig. 5.

[0026] Once assembled and pre-charged, one or more of the single phase collection apparatus 20 is inserted into the multi-chamber section ("MCS") of a formation evaluation tool to collect formation samples. As the tool is lowered down into the wellbore, the open port 15 of the end cap 4 is exposed to mud at hydrostatic pressure and the nitrogen charging piston 3 is forced upwards once hydrostatic pressure is greater than the initial nitrogen gas pressure, compressing the nitrogen gas within the nitrogen gas chamber 6 so that the pressure of the nitrogen gas equals the hydrostatic pressure, as in Fig. 6.

[0027] When a sample is to be taken, the appropriate valve of the MCS is opened and the desired formation fluid is pumped into the collection chamber **2**, thereby forcing both the sample piston **1** and the nitrogen charging piston **3** downward towards the case adaptor **11** as shown in Fig. 7. Mud is forced out of the open port **15** of the end cap **4** as both the sample piston **1** and the nitrogen charging piston **3** move downwards. Once the nitrogen charging piston **3** engages the case adaptor **11**, the pressure of both the sample and the nitrogen gas increases as pumping continues. Once the desired overpressure has been attained, the MCS valve is closed trapping the sample and the nitrogen gas at a pressure above hydrostatic.

[0028] As the collection apparatus **20** is retrieved from the wellbore, the formation sample shrinks as the sample cools. However, the highly compressible nitrogen gas acting against the sample piston **1** maintains the pressure of the sample above the bubble point.

[0029] At the surface, a shipping end cap replaces the end cap **4** for transportation and storage. If cool temperatures are expected during shipping, additional fluid can be pumped in through the shipping end cap to compress the nitrogen further, thereby helping to maintain the sample at a high pressure.

[0030] The removal of the sample from the collection apparatus **20** is accomplished using conventional techniques to remove formation samples from a sample bottle. Thus, fluid is pumped in to the collection apparatus **20** to force the sample out of the collection chamber **2**.